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The Point-Source Repository Assumption and Predicted Individual Doses*

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INTRODUCTION

Predicting doses to individuals who live near a nuclear waste repository requires careful modeling of the repository excavation, its backfill, and its effect on surrounding hydrologic conditions. Availability of waste to individuals always starts with radionuclide release from one of many spatially separated canisters in a repository. The transport of waste from each canister to an individual can occur by many different pathways. An observer, were he able to follow the migration of the many waste pulses to a biosphere release point, would see a system of pulses moving through various pathways, at different times, and finally impacting a biosphere release point.

Point-source repository (PSR) models, which in many cases have only a single sequence of pathways to a release point, ignore network detail, spatial separation and branching that occur within a real repository.[1-3] The spatial extent of a repository leads to initial dilution of the radioactivity within the repository. Since dilution is important for calculating individual doses, a model has been developed to study network effects on dilution.

In this work we consider distances to about 5 km. This requires careful calculation of the trajectory of the release plume from each canister. Our model provides the sort of relative effects which might be obtainable by designing and modifying hydrologic networks and their physical attributes so as to reduce individual doses. Also, when comparing absolute values of the impacts of nuclear power generation with other technologies, say, coal-fired generation of power, it is unwise and possibly misleading to assume worst-case values in one technology which could lead to results that are orders of magnitude too high for that technology, especially when commensurate assumptions cannot be made in other technologies. The PSR assumption is such a worst-case assumption when it is used to predict individual doses which are used for comparison with other hazards.

MODELING APPROACH

We have linked several LLNL numerical tools to determine the approximate magnitude of conservatism inherent in the point-source repository assumption. The intent was to build a model that allows individual dose to be sensitive to repository network features (RNF). By varying the network of an RNF model from (1) a point source model to (2) a detailed network model with multiple source terms, multiple boundary conditions, and multiple pathways, a relative measure of the conservatism of the PSR model is obtainable.

The RNF model is designed to specify more repository detail by approximating the flow field with linked one-dimensional flow-path segments. The solution of the convective-diffusion equation for waste transport is approximated by a Gaussian-shaped pulse versus time.

We have assumed three different radionuclide groups: the actinides, the cation fission products and the anion fission products. Each group moves within a flow path with a characteristic velocity specified by its K_d for that path.[4] To avoid costly integrations over initial pulse configurations, we have assumed time-truncated Gaussians with radioactivity contained between plus and minus two standard deviations.

RESULTS

Calculations show that substantial reductions in peak individual dose can occur when a detailed network model is employed rather than a PSR model. In fact, in some scenarios where MPC_W at a biosphere release point is predicted to be exceeded by a PSR model, we found that network effects can reduce these doses to acceptable levels; thus, the excess dose can be attributed to the PSR assumption or to poor repository design, not to unalterable site physical conditions.

Another dose reducing effect is that all canisters do not release their radionuclides simultaneously. In fact, individual canisters will be surrounded by different hydrologic conditions. These conditions will affect the time when releases occur. In lieu of information required to correlate canister corrosion rates to hydrologic conditions, we have used uncorrelated probability distribution functions for canister times of release and pulse widths. Varying the standard deviation of these parameters has a similar effect to varying the transport dispersion coefficient. A larger standard deviation in the initial-release-time parameter, for example, tends to dilute the radioactivity and thus lower the peak dose; however, for some scenarios individual doses can be increased because short-lived radionuclides escape which would not escape for smaller standard deviations.

Some sensitive parameters in PSR models[5] are shown here to have less sensitivity on peak dose in a network model. This happens because a network model shadows these effects due to its many sources, pathways, and times of release. For example, we have studied the effect of choosing a Gaussian-shaped pulse as an approximation to a more exact solution to the convective-diffusion transport equation. It was found that the functional form of the pulse's shape has less effect on peak dose for an RNF model than for a PSR model. The main reason for this insensitivity in the RNF model was found to be that an individual drinking from a water well, for example, is actually being affected simultaneously by many pulses of radioactivity, especially around the time of peak dose. The value of peak dose is more strongly affected by the timing of pulses than it is by the shape of pulses.

SUMMARY

The PSR assumption can result in substantial over prediction of peak individual doses. Hydrologic engineering of the flow paths of a repository can cause dramatic changes in near-field doses.

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